Variable-Resolution Dynamic Contrast-Enhanced Breast MRI Acquisition

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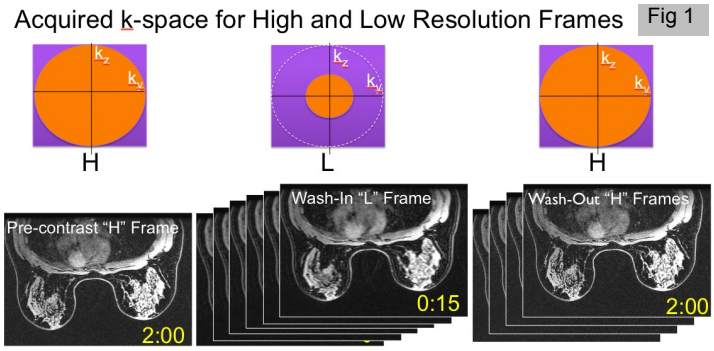
Purpose: Dynamic-contrast enhanced (DCE) MRI is a standard element of clinical breast protocols, and is challenging due to the need for both high spatial and high temporal resolution [1-3]. High temporal resolution is needed for accurate pharmacokinetic modeling and high spatial resolution for clear depiction of tumor morphology. Although some imaging protocols include a combination [2] of rapid, low-resolution scans and slower high-resolution scans, these can cause practical complications such as delays and/or accidental changes to parameters (like gain) that could render the acquisition useless for quantifying contrast uptake. Here we present a simple, single scan technique that acquires variable temporal and spatial resolution images seamlessly switching between the modes, with the timing tailored to the contrast dynamics in breast imaging.

Methods: The pulse sequence acquires low (L) and high-resolution (H) phases according to a preset schedule by restricting acquisition to a smaller or larger radius k_r in elliptical k-space (Fig 1). The scan schedule was as follows- H…LL^LLLLLLLLLLHHH, where … denotes a pause to assess image quality and to prepare for contrast injection (indicated by ^). The reconstruction was identical for L and H frames, with simple zero filling in k-space for L frames, allowing direct comparison of locations despite variable resolution. We used a dual-echo bipolar readout 3D SPGR sequence with a 2-point Dixon algorithm [4] for fast and reliable water/fat separation, which is particularly useful at 3T where some fat suppression schemes are subject to B_1-variation-induced shading. Following informed consent and under IRB guidelines, we tested this technique on 5 volunteers and 2 patients with breast cancer on GE 3T Discovery 750 system using a vendor supplied 8-channel breast phased-array coil. Scan parameters were as follows: 3D axial slab, 312x300 matrix, 160 1.2 mm thick sections, TR/TE1/TE2 4.5ms/1.3ms/2.4ms, flip angle 13º, ±167 KHz bandwidth, ARC parallel imaging with 1.6 acceleration factor along k_y (left/right). We acquired one pre-contrast high resolution phase, followed by 12 high temporal resolution phases, then 3-5 high spatial resolution phases for washout characterization. The high spatial resolution phases were of two-minute duration and the high temporal resolution phases were on the order of 15s. The spatial resolution of the high temporal resolution phase was roughly one-third of that of the high spatial resolution in y and z dimensions and unaltered along x.



Results: Figure 2a shows 16 phases of the same section (inset zoom-in of tumor) acquired using our sequence on a patient with a rim enhancing invasive ductal carcinoma. The first phase and the last three phases were high spatial resolution (120s per slab) while the intervening phases were high temporal resolution (15s per slab). The 3D slab was 160 sections with 1.2 mm section thickness. Fig 2b shows a representative section from the acquired axial slab illustrating the excellent spatial resolution and uniform fat suppression of the 3D SPGR-Dixon technique. Fig 2c shows the enhancement curves from three different regions inside the heterogeneously enhancing tumor (ROIs in Fig 2b) demonstrating the high temporal resolution of the sequence as well as the ability to combine low and high spatial resolution data for post-processing.

Discussion: We have developed and tested a simple robust sequence for variable resolution DCE MRI and demonstrated it on patients with breast cancer. Some Gibbs ringing can be observed in the L phases due to the zero filling which can be reduced or eliminated in future using view sharing and/or compressed sensing. Using our technique, we eliminated delays in switching between acquisitions, patient movement due to perceived end of scan and potential errors from different prescan parameters. It also generated all the images in a single series for easy post-processing. Overall, this approach will be of tremendous practical significance in streamlining breast protocols.

References: 1. Turnbull. NMR Biomed. 22:28-39 (2009) 2. Pinker et al. Invest. Radiol. 44:553-8 (2009) 3. Kuhl et al. Radiol. 236:789–800 (2005) 4. Ma et.al. MRM 52: 415-419 (2004)

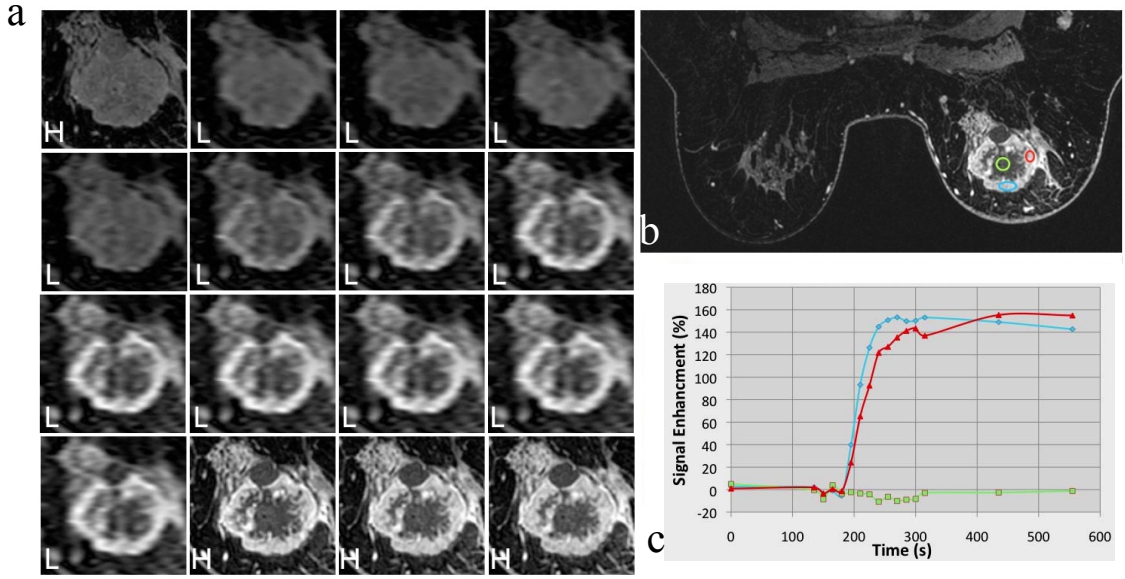


Figure 2. Sixteen phases of a single section through the tumor (zoomed) acquired on a patient with a rim-enhancing invasive ductal carcinoma. The first phase and the last three phases are high spatial resolution and the middles 12 phases are high temporal resolution (15s). A representative axial slice is shown in (b) with ROIs and the corresponding uptake curves for the ROIs plotted in (c).